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Abstract

We extend the Arrow-Fisher-Hanemann-Henry (AFHH) and Dixit-Pindyck (DP) option values to game situations. By reinterpreting the AFHH option value as a change in the surplus from conservation because of the prospect of future information, we deal with the conceptual difficulty associated with the AFHH option value in the presence of strategic interactions. We then introduce the DP option value into a game situation. We show that the equivalence between the expected value of information and the DP option value in the standard model does not hold under strategic interactions.

Keywords: Irreversibility, Quasi-option values, Biodiversity, Uncertainty, Value of Information

JEL classification codes: C72, H43, Q50.

1 Introduction

The value of the prospect of future information is often ignored in the standard analysis of net present value. Ignoring it, however, tends to bias the decisions. In private investment analysis, future information may allow the investors to make state-contingent decisions and thereby avoid unnecessary sunk costs. As Dixit and Pindyck (1994) emphasize, the opportunity cost due to the forgone opportunity to delay the investment, or the Dixit-Pindyck (DP) option value, must be included in the cost of immediate investment in addition to direct investment costs.

The prospect of future information also plays an important role in the analysis of public projects. Suppose, for example, that a policy maker has to choose whether to develop or conserve a forest. The forest may (or may not) contain economically valuable plants, but such plants may be discovered only in the future (say, by independent scientific research), if they exist in the forest at all. Then, ignoring the possibility of the future discovery of plants will bias the current decision towards development. Therefore, the policy maker has to incorporate the Arrow-Fisher-Hanemann-Henry (AFHH) option value due to Arrow and Fisher (1974), Henry (1974), Fisher and Hanemann (1987), and Hanemann (1989), also called the quasi-option value, into the analysis to reflect this possibility. This concept is related to but generally different from the (unconditional) expected value of information (EVI) (Conrad, 1980; Hanemann, 1989). The AFHH option value is also related to the DP option value. In fact, Fisher (2000) claimed that they are identical, though this argument was subsequently proved incorrect by Mensink and Requate (2005).

In the studies of the AFHH and DP option values, the presence of a single decision-maker is typically assumed. For example, when there is a social planner who can stipulate the action of each player in the society, it is sufficient to have only one decision maker in the model. Even if this is not the case, when the market is competitive and each player has negligible impacts on other players, a single decision-maker model would still be appropriate.

However, in many practical situations, the single decision-maker model is not appropriate. The policy-maker may have to take the competition among firms or different public entities as given. A firm may compete with only a few other firms in the same industry and its decision may have non-negligible impacts on other firms.

This is important, because the AFHH option value is conceptually problematic in the presence of strategic interactions, as some outcomes may not be supported as an equilibrium, as argued by Fujii and Ishikawa (2012). Furthermore, the EVI for the society critically depends on how the information is held and released. They have shown that the prospect of future information could even be harmful to everyone in the society, a situation that never happens in a single decision-maker model. Therefore, we cannot appropriately take the prospect of future information into account without taking into account the strategic interactions in the society.

In this study, we extend Fujii and Ishikawa (2012) in two ways. First, we provide an alternative interpretation to the AFHH option value. In this interpretation, the AFHH option value is taken as the change in a surplus measure for development (or immediate investment) because of the prospect of future information. This allows us to overcome the conceptual difficulties pointed out by Fujii and Ishikawa (2012) and to define the AFHH option value even in the presence of strategic interactions. However, unlike the case of a single decision-maker, studied by Hanemann (1989), our AFHH option value cannot be interpreted as the conditional value of information.

Second, we also extend the discussion on the relationship between AFHH and DP option values by Fisher (2000) and Mensink and Requate (2005) to a game situation. We argue that whether the AFHH option value is more relevant than the DP option value would depend on the degree of control that the regulator has on the strategic interactions in the society. We also show that the DP option value in the single decision-maker case is identical to the EVI, but this equivalence does not hold in the presence of strategic interactions. These points reinforce the finding of Fujii and Ishikawa (2012) that social cost-benefit analyses require a careful assessment of strategic interactions.

This paper is organized as follows. In Section 2, we set up a simple model of an irreversible decision under strategic interactions first proposed by Fujii and Ishikawa (2012). This model is a straightforward extension of the single decision-maker model widely used in the literature. Because we adopt the same model and notations as Fujii and Ishikawa (2012), we only provide a brief summary below and omit a detailed discussion on the motivation of the way the model is formulated. In Section 3, we introduce the AFHH and DP option values in the standard single decision-maker case. Most of the results in this section, except for Proposition 1, are not new, but they serve as a reference case. We then extend the AFHH and DP option values to a game situation in Section 4. Section 5 provides some discussion.

2 Setup

There are two time periods: periods 1 (current period) and period 2 (future period). The future state is uncertain. The state s takes a good state s_1 with probability π and a bad state s_2 with probability $1-\pi$. There are two risk-neutral players α and β, each of whom cares only about their own payoff, and a regulator. In each period, each player $i \in \{\alpha, \beta\}$ takes an action, $d_t^i \in \{0, 1\}$, where $d_t^i = 0$ represents conservation (or no immediate investment in the context of the DP option value) and $d_t^i = 1$ represents development (or immediate investment). The decision to develop is irreversible and thus $d_1^i \leq d_2^i$. With a slight abuse of notation, we denote the sequence of actions taken by player i by $d^i \equiv (d_1^i, d_2^i)$. For the simplicity of argument, we assume that each player always chooses to develop if the player is indifferent between conservation and development.

We normalize the payoffs so that the player receives a payoff of zero in each period he chooses conservation. We assume that the total payoff in present value for the two players from development is a in period 1 and $b \cdot \mathrm{Ind}(s = s_1) - c \cdot \mathrm{Ind}(s = s_2)$ in period 2 for positive constants a, b, and c, where $\mathrm{Ind}(\cdot)$ is an indicator function that takes value one if the argument is true and zero otherwise. Therefore, development is beneficial to the society in the good state and harmful in the bad state. We assume that the total payoff is shared equally by the two players when they take the same sequence of actions. When one player chooses a sequence $(1, 1)$ (i.e., development in both periods) and the opponent chooses a sequence $(0, 1)$ (i.e., conservation in period 1 and development in period 2), the leader [follower] of development, who chooses the sequence $(1, 1)$ $[(0, 0)]$, takes a share of k $[1 - k]$ in the total payoff from the development in period 2 for some constant $k \in (0, 1)$.

We assume that new information becomes available to the regulator so that the regulator knows the true state after period 1 but before actions are taken by players in period 2. We use the hat $(\hat{})$ and the asterisk $({}^*)$ notations to denote the cases with and without the prospect of future information, respectively. Furthermore, we use the tilde $(\tilde{})$ notation to denote the case where the option to delay the decision to develop is not available, which corresponds to the case where the sequence $(0, 1)$ is not allowed. We also assume that the game structure and probability distribution of the states are common knowledge and that the regulator tries to maximize the expected total payoffs in the society (i.e., the sum of the payoffs for players α and β) for the two periods, which we refer to as the social welfare. The latter assumption can be justified when the regulator can transfer the payoffs between the players in a lump-sum manner.

3 Case (I): Social planner

As with Fujii and Ishikawa (2012), we start with the case where the regulator is a social planner, who can stipulate the action of each player. This is *de facto* a single decision-maker case. Because the social welfare is determined only by the timing of development and not by who chooses to develop, we simply impose $d^\alpha = d^\beta$ in this section. This allows us to avoid unnecessary complications and treat the action of player α as the action of a representative player. Given the setup presented in Section 2 and assuming a rational choice in period 2, we can write the value functions, or the social welfare, as a function of the current action d_1^α, in the following manner[1]:

$$\hat{V}(d_1^\alpha) = B + (a - C) \cdot \mathrm{Ind}(d_1^\alpha = 1) \quad (1)$$

$$V^*(d_1^\alpha) = \max(B - C, 0) \cdot \mathrm{Ind}(d_1^\alpha = 0) + (a + B - C) \cdot \mathrm{Ind}(d_1^\alpha = 1) \quad (2)$$

Thus, the social planner chooses d_1^α to maximize $\hat{V}$ $[V^*]$ in the presence [absence] of the prospect of future information. Using these value functions, the AFHH option value can be found as follows:

$$OV_{\mathrm{I}}^{AFHH} \equiv (\hat{V}(0) - \hat{V}(1)) - (V^*(0) - V^*(1)) = \hat{V}(0) - V^*(0) = \min(B, C). \quad (3)$$

The AFHH option value can be interpreted as the correction term that must be added to the net present value of conservation relative to development when the net present value is calculated ignoring the prospect of future information. The third expression shows that the AFHH option value is the change in the expected total payoff for the society from the prospect of future information, given that conservation is chosen in period 1. Thus, the AFHH option value can be interpreted as the conditional value of information (Hanemann, 1989).

It is also possible to give the AFHH option value an alternative interpretation. We can interpret $\hat{\theta}_{\mathrm{I}} \equiv \hat{V}(0) - \hat{V}(1)$ as a surplus measure of conservation relative to development when future information is available. This is the minimum transfer of payoff that must be given to the regulator to ensure development takes place in period 1. In the current setup, this is the smallest number that has to be added to a to make the regulator indifferent between conservation and development in period 1. This number is negative if the regulator prefers development to conservation. We can similarly define θ_{I}^* for the case without the prospect of future information. Given these definitions, we have $OV_{\mathrm{I}}^{AFHH} = \hat{\theta}_{\mathrm{I}} - \theta_{\mathrm{I}}^*$. As we argue in the next section, this alternative interpretation allows us to define the AFHH option value in a game situation.

Mensink and Requate (2005) argue that the DP option value can be defined as follows:

$$OV_{\mathrm{I}}^{DP} \equiv \max\left(\hat{V}(0), \hat{V}(1)\right) - \max\left(\bar{B}_0, V^*(1)\right), \quad (4)$$

where $\bar{B}_0$ is the default value in the net present value decision rule. It reflects the present value of the stream of payoffs that would emerge if no investment decision is made at any time. In our

[1]See Fujii and Ishikawa (2012) for the derivation of this result.

model, this is equal to choosing conservation in both periods, which implies that $\bar{B}_0 = 0$. In this definition, the regulator is assumed to commit in period 1 to either conservation or development for both periods under the net present value decision rule. Thus, the DP option value can be thought of as the value arising from the flexibility to delay the decision to develop (or invest).

A concept related to the AFHH and DP option values is the EVI defined as follows:

$$EVI_{\mathrm{I}} \equiv \max\left(\hat{V}(0), \hat{V}(1)\right) - \max\left(V^*(0), V^*(1)\right). \tag{5}$$

The EVI is the additional expected total payoff from the future information. If we define $\hat{W}_{\mathrm{I}} \equiv \max\left(\hat{V}(0), \hat{V}(1)\right)$ and $W_{\mathrm{I}}^* \equiv \max\left(V^*(0), V^*(1)\right)$, they can be interpreted as the social welfare when the regulator behaves rationally given the availability of future information. Thus, $EVI_{\mathrm{I}} = \hat{W}_{\mathrm{I}} - W_{\mathrm{I}}^*$ is the change in the social welfare from future information. Similarly, if we define $\tilde{W}_{\mathrm{I}}^* \equiv \max(\bar{B}_0, V^*(1))$, $OV^{DP} = \hat{W}_{\mathrm{I}} - \tilde{W}_{\mathrm{I}}^*$. It turns out, however, that the DP option value is identical to the EVI in the current setup:

Proposition 1 *Given the setup in Section 2, we have the following:*

$$OV_{\mathrm{I}}^{DP} = EVI_{\mathrm{I}} = (C - a) \cdot \mathrm{Ind}(a \leq C < a + B) + B \cdot \mathrm{Ind}(a + B \leq C) \tag{6}$$

We omit the formal proof because it is straightforward. Intuitively, the result can be understood in the following manner. When there is no prospect of future information, the social planner simply loses the opportunity cost, a, when he chooses to conserve in period 1. Therefore, a rational social planner chooses either $(0, 0)$ or $(1, 1)$; he never chooses $(0, 1)$. Therefore, even though $V^*(0) \neq 0$ in general, this occurs only when $V^*(1) = \hat{V}(1) > V^*(0) > 0$, in which case we have $\max(V^*(0), V^*(1)) = \max(0, V^*(1)) = V^*(1) = \hat{V}(1)$.

Put differently, the prospect of future information can only make conservation more attractive in period 1. Hence, if development is more attractive than conservation in period 1 in the absence of information, then development is certainly more attractive in period 1 in the presence of information. In this case, the DP option value and EVI are both zero because it does not help the regulator to have flexible decision or the prospect of future information. In the absence of information, conservation must be more attractive than development in period 2, if it is more attractive in period 1. In this case, $V(0) = 0$ must hold, equating OV_{I}^{DP} with EVI_{I}.

By comparing Eq. (3) and Eq. (6), we have the following proposition:

Proposition 2 *OV_{I}^{AFHH}, OV_{I}^{DP}, and EVI_{I} satisfy the following relationship:*

$$EVI_{\mathrm{I}} = OV_{\mathrm{I}}^{DP} = OV_{\mathrm{I}}^{AFHH} \cdot \mathrm{Ind}(a < C) + PPV \cdot \mathrm{Ind}(a + B > C > a) \quad (\geq 0), \tag{7}$$

where $PPV \equiv V^*(0) - V^*(1) = -a + \max(0, C - B)$ is what Mensink and Requate (2005) call the pure postponement value. Clearly, $EVI_{\mathrm{I}} = OV_{\mathrm{I}}^{DP} = OV_{\mathrm{I}}^{AFHH}$ when $a + B < C$. However, as Hanemann (1989) has shown, $OV_{\mathrm{I}}^{AFHH} \neq EVI_{\mathrm{I}} (= OV_{\mathrm{I}}^{DP})$ in general. In fact, Eq. (7) is simply a restatement of Eq. (17) in his paper and the generalization of the results presented by Mensink and Requate (2005). Thus, the results presented here are not new, except for Proposition 1. However, the case of the social planner serves as a reference case.

4 Case (II): Strategic interactions

In this section, we let the players interact strategically with each other. That is, each player chooses his action so as to maximize his payoff for the two periods. As with Fujii and Ishikawa (2012), we take the efficient subgame perfect Nash equilibrium as the relevant solution concept. The subgame played in period 2 is determined by the action profile $(d_{\mathrm{I}}^{\alpha}, d_{\mathrm{I}}^{\beta})$ in period 1.

Given the setup in Section 2, each player $i \in \{\alpha, \beta\}$ has three possible pure strategies $d^i \in \{(0,0), (0,1), (1,1)\}$ when future information is not available. When information is available in period 2, each player can take a state-contingent action. Therefore, if conservation is chosen in period 1, the set of strategies for player i in the subgame in period 2 is $\{0, \mathrm{Ind}(s = s_1), \mathrm{Ind}(s = s_2), 1\}$. However, because $\mathrm{Ind}(s = s_1)$ dominates the other strategies, we only need to consider the following two strategies $d^i \in \{(0, \mathrm{Ind}(s = s_1)), (1,1)\}$. The payoff matrices for these cases are given in Table 1.

With some slight abuse of terminology, we shall use the cell index in Table 1 to specify a profile of the sequence of actions. For example, b*) refers to the profile $(d^{\alpha}, d^{\beta}) = ((0,0), (0,1))$. The equilibrium profile in the absence of future information is: a*) if $C - B > a$; e*) if $a < (1/2 - k)(B - C)$ and $k < 1/2$; i*) if $a \geq C - B \geq 0$ or $a \geq (1 - 2k)(B - C) \geq 0$; and f*) or h*) otherwise. In the presence of future information, the equilibrium is: â) if $a < (1 + \mathrm{Ind}(k \geq 1/2))(k - 1/2)B + C$; $\hat{\mathrm{d}}$) if $a \geq (1 - 2k)B + C$; and $\hat{\mathrm{b}}$) or ĉ) otherwise.[2]

We can now introduce the EVI and the AFHH and DP option values for the society in the

[2]When we have multiple asymmetric equilibria, we can choose an arbitrary equilibrium because the choice does not affect the social welfare.

Table 1: The *ex ante* expected payoff matrix for two periods when no information is available in period 2 (top) and the corresponding matrix when information is available in period 2 (bottom). The borders define the subgame to be played in period 2.

d^α \ d^β		$(0,0)$		$(0,1)$		$(1,1)$
$(0,0)$	a^*)	$(0,0)$	b*)	$(0,B-C)$	c*)	$(0,a+B-C)$
$(0,1)$	d*)	$(B-C,0)$	e*)	$((B-C)/2,(B-C)/2)$	f*)	$((1-k)(B-C),a+k(B-C))$
$(1,1)$	g*)	$(a+B-C,0)$	h*)	$(a+k(B-C),(1-k)(B-C))$	i*)	$((a+B-C)/2,(a+B-C)/2)$

$d_2^\alpha(s)$ \ $d_2^\beta(s)$		$(0,\mathrm{Ind}(s=s_1))$		$(1,1)$
$(0,\mathrm{Ind}(s=s_1))$	â)	$(B/2,B/2)$	$\hat{\text{b}}$)	$((1-k)B,a+kB-C)$
$(1,1)$	ĉ)	$(a+kB-C,(1-k)B)$	$\hat{\text{d}}$)	$((a+B-C)/2,(a+B-C)/2)$

current context. As Fujii and Ishikawa (2012) argue, the EVI in this case is simply the change in the expected total payoff for the two periods due to the information. Let $\hat{W}_{\text{II}}$ and W^*_{II} be the equilibrium social welfare (i.e., the expected total payoff in the equilibrium for the two players summed over the two periods). For example, when $C - B > a$, the equilibrium is $\hat{a}$) and a^*) with and without information in period 2, respectively, and thus we have $\hat{W}_{\text{II}} = B$ and $W^*_{\text{II}} = 0$. Using $\hat{W}_{\text{II}}$ and W^*_{II}, we can define and compute the EVI for the current case as follows:

$$EVI_S \equiv \hat{W}_{\text{II}} - W^*_{\text{II}} \tag{8}$$

$$= \begin{cases} C-a & \text{if} \quad (a+(2k-1)B < C \le a+B \quad \text{and} \quad k \ge \frac{1}{2}, \\ & \text{or if} \quad \max\left(a+(k-\frac{1}{2})B, B-\frac{2a}{1-2k}\right) < C < B+a \quad \text{and} \quad k < \frac{1}{2} \\ B & \text{if} \quad C > B+a \\ C & \text{if} \quad C < B - \frac{2a}{1-2k} \quad \text{and} \quad k < \frac{1}{2} \\ 0 & \text{if} \quad \text{otherwise.} \end{cases} \tag{9}$$

To apply the DP option value in the current case, we need to consider the change in the social welfare due to the flexibility to delay the decision. When the players can choose a state-contingent action, the social welfare is clearly $\hat{W}_{\text{II}}$. The question is, therefore, what the relevant social welfare is under the net present value decision rule, when the flexibility is ignored. We argue that the regulator in this case would be able to distribute a development right free to the players in period 1. This right can be exercised only in period 1. Thus, the player has to commit to development or conservation in period 1. They cannot choose the sequence $(0, 1)$. Therefore, the equilibrium in the absence of future information is a*) if $C > a + B$ and i*) otherwise. We denote the equilibrium social welfare by $\tilde{W}^*_{\text{II}}(= \max(0, a + B - C))$. With these considerations, we can now define the DP option value for the current case.

$$OV_S^{DP} \equiv \hat{W}_{\text{II}} - \tilde{W}^*_{\text{II}}. \tag{10}$$

Notice that this definition coincides with OV_{I}^{DP}, if the regulator can stipulate the action of each player. It is straightforward to show the following:

Proposition 3 *From Eqs. (9) and (10), we have:*

$$EVI_S = OV_S^{DP} + a \cdot \text{Ind}(a < (1/2 - k)(B - C) \quad \text{and} \quad k < 1/2). \tag{11}$$

Proposition 3 shows that the equivalence between the EVI and DP option values does not hold when $a < (1/2 - k)(B - C)$ and $k < 1/2$. This is because development takes place only in period 2 under this condition, a result that is not expected from Case (I). This also underscores the point that cost-benefit analysis calls for a careful assessment of the default value in the presence of strategic interactions.

A notable point here is that both EVI and DP option value can be negative. Fujii and Ishikawa (2012) have shown that EVI is negative if and only if $k < 1/2$, $C < a$, and $2(a-C)/(1-2k) < B < C+2a/(1-2k)$. The DP option value is negative if and only if $0 > C-a > (k-1/2)B$, which holds only if $k < 1/2$. Therefore, having additional information or flexibility to delay the decision can actually harm the social welfare.

Now, let us turn to the AFHH option value in the current case. Fujii and Ishikawa (2012) have shown that the AFHH option value has a conceptual difficulty in the presence of strategic interactions because the value function is not meaningful when a particular outcome (i.e., development or conservation) is not supported as an equilibrium. To circumvent this problem, we adopt the alternative interpretation of the AFHH option value and extend it to a game situation by first considering surplus measures $\hat{\theta}$ and θ^* of conservation. We define them as the minimum amount of payoff that can be added to a to support development as an equilibrium. Notice that a is positive [non-positive] when the equilibrium outcome is conservation [development].

According to this definition, the surplus measure can be found by looking at the difference in the individual payoffs between conservation and development when the opponent is choosing development. When the information about the state becomes available in period 2, this can be done by taking the difference of the payoff for player α [player β] between cells â) and ĉ) [cells â) and $\hat{\text{b}}$)].

$$\hat{\theta}_{\text{II}} = \frac{B}{2} - (a + kB - C) = \left(\frac{1}{2} - k\right) B + C - a. \tag{12}$$

When the information is not available, we can compute θ^* in the following manner. Using the backward induction, the reduced payoff matrix consists of e*), f*), h*), and i*) when $B > C$, and a*), c*), g*), and i*) when $B \le C$. Therefore, we have:

$$\theta^*_{\text{II}} = ((1/2 - k)(B - C) - a) \cdot \text{Ind}(B > C) - (a + B - C)\,\text{Ind}(B \le C). \tag{13}$$

Using Eqs. (12) and (13), we can define the AFHH option value for the current case as follows:

$$OV_S^{AFHH} \equiv \hat{\theta}_{\rm II} - \theta_{\rm II}^{*} = (3/2 - k)\min(B, C) = (3/2 - k)OV_{\rm I}^{AFHH}(> 0). \tag{14}$$

There are five points to note here. First, our definition of OV_S^{AFHH} is a direct extension of $OV_{\rm I}^{AFHH}$. If the regulator can stipulate the actions of the two players, OV_S^{AFHH} coincides with $OV_{\rm I}^{AFHH}$.

Second, Eq. (14) clearly shows that the change in the surplus measure of development because information is influenced by strategic interactions. It also shows that $OV_S^{AFHH} = OV_{\rm I}^{AFHH}$ if and only if $k = 1/2$. This is because the strategy taken by the opponent does not change the incentive structure when $k = 1/2$. For example, in the absence of the prospect of future information, each player chooses to develop in this case if and only if $a + B - C \geq 0$ regardless of the opponent's strategy.

Third, while we have successfully extended the definition of AFHH option value, the point made by Fujii and Ishikawa (2012) is still valid. That is, some outcomes are not supported as an equilibrium, and thus the standard value functions used in Case (I) are not meaningful. This also means that it is not possible to interpret OV_S^{AFHH} as the conditional value of information, unlike the single decision-maker case studied by Hanemann (1989).

Fourth, Eq. (14) shows that the AFHH option value is positive. The AFHH option value in the current case is the change of payoff needed to induce development in light of the prospect of future information. Since the prospect of future information makes conservation more attractive in period 1, the results are intuitive. Option value tends to be higher when k is lower, because the players face stronger incentives to conserve in period 1 when information will become available in period 2. That is, in addition to the fact that they can choose to develop only when the state is good, they can also enjoy a higher share of b if they are the follower in development. Fifth, the AFHH option value is different from the DP option values and the EVI, which would not be surprising given Proposition 2.

5 Discussion

In this study, we have extended the AFHH and DP option values to a game situation. One novelty of this study is that, by reinterpreting the AFHH option value as the change in the surplus of development because of future information, we have overcome the conceptual difficulty of the AFHH option value pointed by Fujii and Ishikawa (2012). While the AFHH and DP option values and the EVI discussed above are related to each other, the appropriate choice of these measures in a practical application of cost-benefit analysis would depend on the policy instruments that are available to the regulator. For example, if the regulator simply passes information to the players with no additional policy instruments, the EVI would be the measure that the regulator would ultimately be interested in. The regulator can choose to pass on the information if and only if EVI is positive.

The AFHH option value will be relevant if the cost-benefit analyst wants to measure the value of development. Unlike the single decision-maker case, this measurement may be complicated in a game situation because the regulator cannot directly implement development. Our approach is to use a minimum hypothetical transfer to induce development. We chose the parameter a for this transfer because this parameter directly changes the net present value of development. However, under some circumstances, the regulator may be able to make, for example, state-contingent transfers. In such a case, the AFHH option value may be altered.

The DP option value is most relevant in a situation where the regulator can choose whether the players have to make a commitment to either conservation or development in period 1, for example, by distributing free development rights in period 1, which can be exercised only immediately. Such a situation may arise in practice because the regulator may be short-lived, in the sense that the opportunity to develop is lost for ever when the person in charge in the regulating body changes.

This study has highlighted the fact that the AFHH and DP option values and the EVI all depend on the way players interact with each other, a point that has largely been neglected in the literature. Therefore, social cost-benefit analyses under strategic interactions require a careful assessment of the information and policy instruments that may be available to the regulator in the future.

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